APPENDIX B

Rainfall and Reference Evapotranspiration

1 GENERAL

This Appendix deals with the weather data used in the project. The Lake Toho ISGM requires rainfall and reference Evapotranspiration (ET).

Table 2-3 contains a list of data files and utility programs that were used to develop the rainfall data used in the model.

2 RAINFALL

SFWMD provided rainfall time-series for 71 gauging stations of which 57 were located inside the project area (see Figure 2-1). Out of these 57 stations only 25 contained data for the model calibration and validation period (1995-2001). All data files contained daily rainfall recordings (inch/day). Some of the 25 stations also contained large data gaps within the calibration period and were therefore omitted. A total of 18 rainfall stations were used in the model.

2.1 Data Format Conversion

All rainfall data were provided by SFWMD in DBHydro format. This ASCII file format was converted into the MIKE SHE T0 time-series format using the convert.exe program (See Table 2-3)

2.2 Gapfilling

Most of the rain series contained a number of data gaps. Most gaps were only a few days (often weekends and holidays) but there were also several larger data gaps with duration of weeks or even months. For all first recordings after a data gap DBHydro indicates whether the value represents cumulated rainfall for the entire gap or whether it's a new daily reading. Rather than calculating an average rainfall rate for a specific data gap (based on cumulated values) it was chosen to remove (manually) all recordings following a data gap and replace all gaps with values from nearby stations as part of the gap-filling procedure.

The DHI MIKE Zero package contains a correlation and gap-filling package that operates on DHI dfs0 file formats (DHI binary time-series format). The T0 data files converted from DBHydro consequently needed conversion to the DHI dfs0 format before using the gap-filling utility. This conversion was made easily by importing T0 files to EXCEL and subsequently using cut-and-paste to the dfs0 time-series editor.

Initially an automated gap filling procedure in the DHI MIKE Zero toolbox was adopted. This procedure calculates correlation coefficients between all time-series. Missing data in a specific time-series are then replaced with values from the time-series with the highest

correlation coefficient. In addition the correlation tool calculates a volume correction factor that are multiplied to the value from the best-correlated station. The correlation coefficients were however poor (0.2-0.8) and the calculated volume correction factors were often unrealistic (down to 0.5). It was therefore chosen to replace missing data with data from the nearest rainfall station. No volume correction was made. Table 2-1 shows, for each rainfall station, the ranking of stations used to replace missing values. For each station the matrix indicates the priority and the number of the station that were used to replace missing values. Thus, for CHEST_R_H6 station number 12 (TOHO15_R_JW235) were used as first priority station, station no. 14 as second priority etc. Table 2-2 shows basic rainfall statistics before and after gap filling.

Table 2-1 Station Ranking Matrix used for Rainfall Gap-Filling

		Priority and Station Number for Gapfilling																
No.	Station ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	CHEST_R_H6	12	14	7	6	17	18	2	3	4	5	8	9	10	11	13	15	16
2	CREEK_R_05841	13	3	6	7	1	4	5	8	9	10	11	12	14	15	16	17	18
3	KIRCHOFF_R_05862	6	7	11	13	1	18	2	4	5	8	9	10	12	14	15	16	17
4	KISS.FS_R_06305	18	8	5	11	10	1	2	3	6	7	9	12	13	14	15	16	17
5	S59_R_16567	9	3	4	11	14	1	2	6	7	8	10	12	13	15	16	17	18
6	S61_R_05868	7	3	11	14	1	2	4	5	8	9	10	12	13	15	16	17	18
7	S61_R_16570	6	3	11	14	1	2	4	5	8	9	10	12	13	15	16	17	18
8	SHING.RG_15323	4	18	10	16	5	1	2	3	6	7	9	11	12	13	14	15	17
9	STCLOUD_R_16619	5	14	12	11	1	2	3	4	6	7	8	10	13	15	16	17	18
10	TAFT_R_06042	16	8	15	5	4	1	2	3	6	7	9	17	11	12	13	14	18
11	TOHO10_R_JW234	6	5	3	9	14	1	2	4	7	8	10	12	13	15	16	17	18
12	TOHO15_R_JW235	14	1	11	9	6	2	3	4	5	7	8	10	13	15	16	17	18
13	L_MARIO2_R_05884	2	3	6	7	1	4	5	8	9	10	11	12	14	15	16	17	18
14	ALL2R_HA469	12	1	9	6	7	2	3	4	5	8	10	11	13	15	16	17	18
15	BEELINE_R_05963	16	10	8	5	9	1	2	3	4	6	7	11	12	13	14	17	18
16	MC_COY_16634	15	10	8	5	9	1	2	3	4	6	7	11	12	13	14	17	18
17	PINE_ISL_R_05876	1	12	14	9	6	2	3	4	5	7	8	10	11	13	15	16	18
18	KISS.FS2	4	8	5	11	10	1	2	3	6	7	9	12	13	14	15	16	17

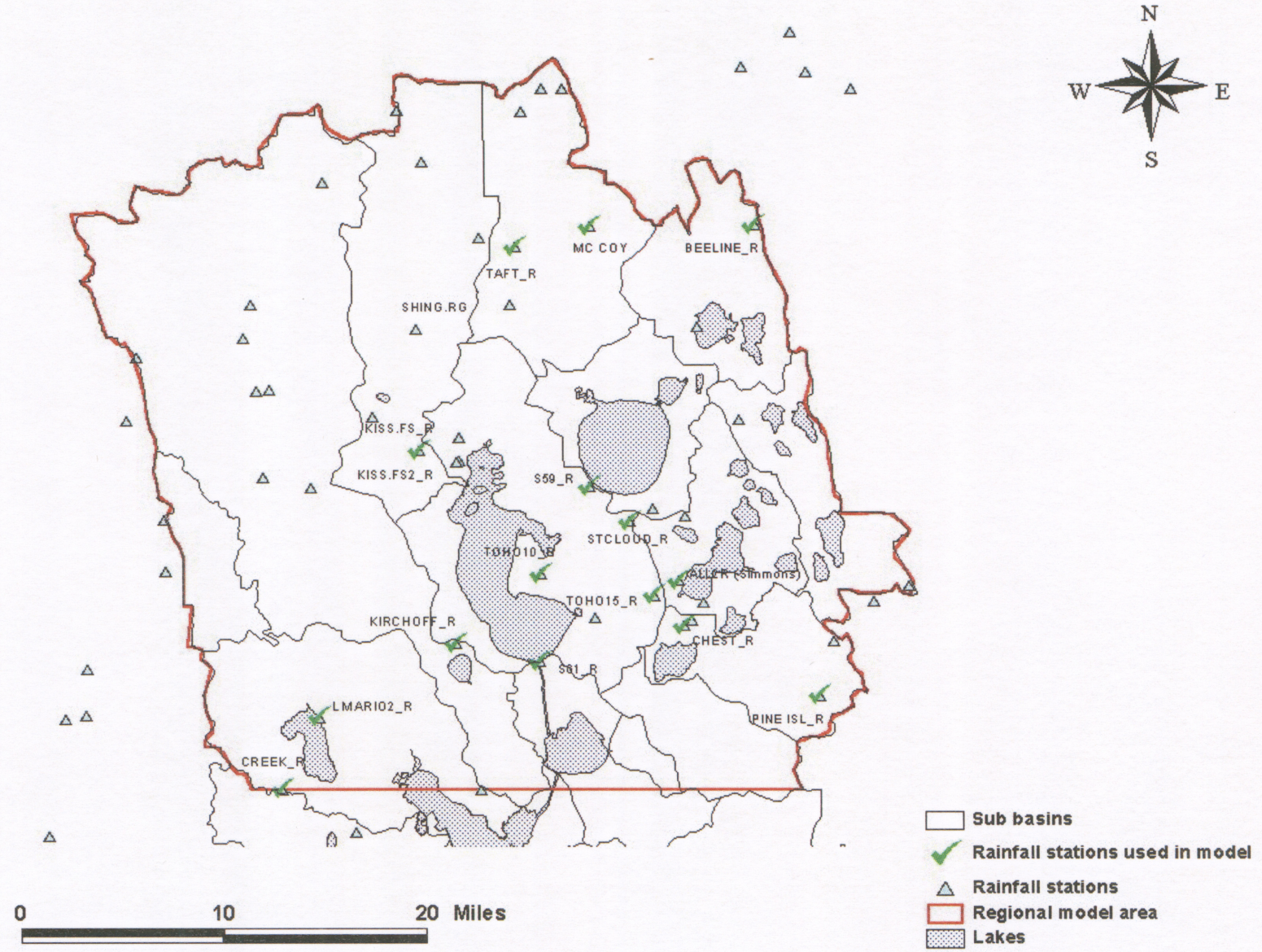

Figure 2-1 Location of Rainfall Stations and Indication of Rainfall Stations Used in the Model

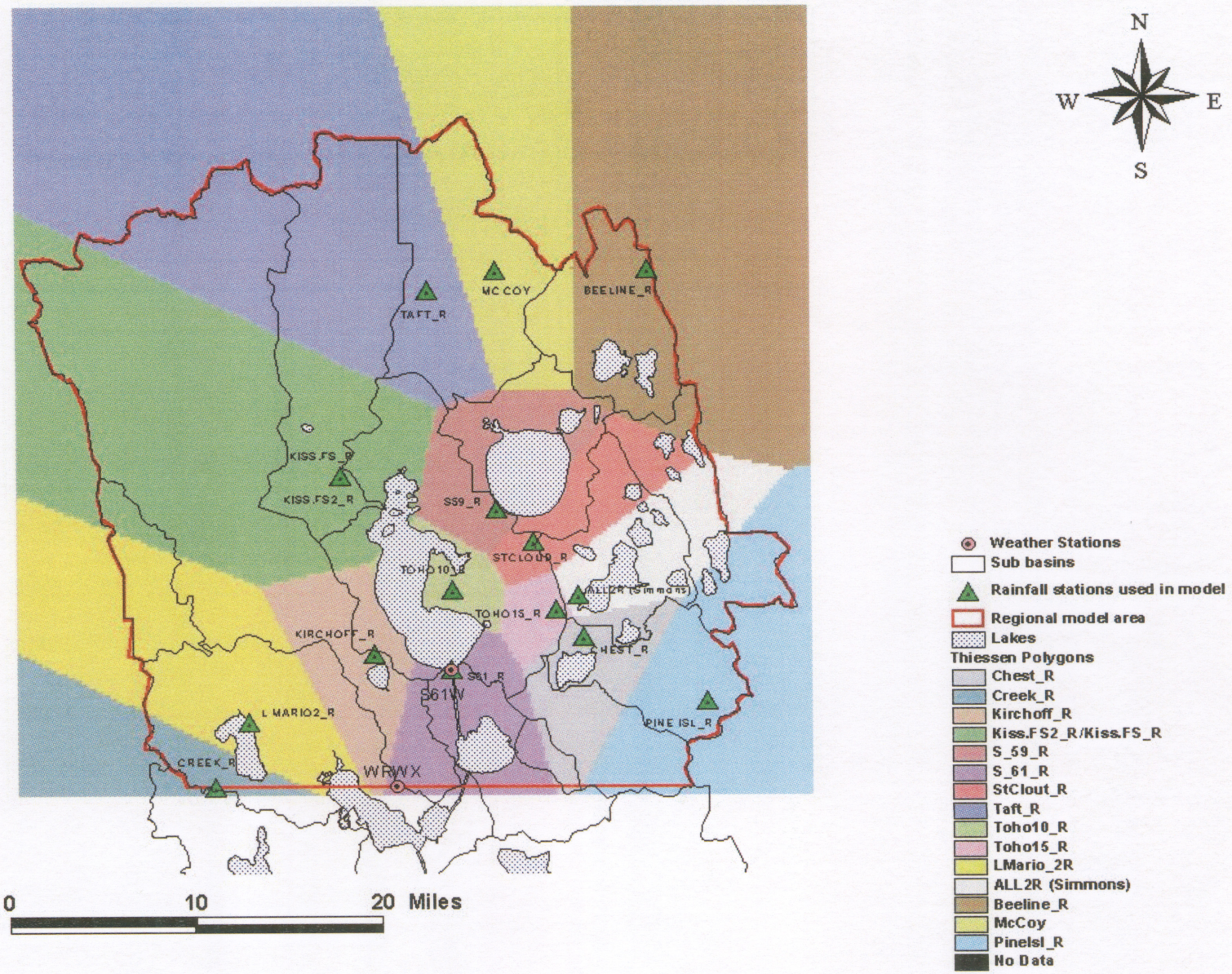

Figure 2-2 Thiessen Polygons Used for Distributing Rainfall Data within the Project Area

Table 2-2 Rainfall Gap Filling Statistics

Station ID	Before Gapfilling								After Gapfilling		
	Number of missing values					Mean Rainfall (1997-2000)			Mean Rainfall (1997-2000)		
	1997	1998	1999	2000	total	inch/day	inch/year	mm/year	inch/day	inch/year	mm/year
CHEST_R_H6070	365	40	0	33	438	0.106	38.70	983.04	0.111	40.63	1032.07
CREEK_R_05841	24	10	12	97	143	0.101	36.98	939.36	0.103	37.70	957.62
KIRCHOFF_R_05862	131	27	33	89	280	0.100	36.49	926.73	0.104	38.03	965.93
KISS.FS_R_06305	104	74	107	38	323	0.092	33.47	850.06	0.123	44.80	1138.02
S59_R_16567	12	0	0	0	12	0.108	39.33	999.09	0.108	39.41	1001.01
S61_R_05868	10	0	0	85	95	0.112	41.02	1041.97	0.119	43.29	1099.62
S61_R_16570	1	3	4	10	18	0.114	41.68	1058.61	0.115	42.06	1068.32
SHING.RG_15323	0	0	0	0	0	0.102	37.14	943.27	0.102	37.14	943.27
STCLOUD_R_16619	3	4	3	216	226	0.123	44.83	1138.80	0.126	46.16	1172.44
TAFT_R_06042	2	0	21	0	23	0.122	44.38	1127.29	0.122	44.49	1129.99
TOHO10_R_JW234	365	365	174	0	904	0.108	39.34	999.14	0.115	42.00	1066.79
TOHO15_R_JW235	365	365	182	0	912	0.107	39.03	991.36	0.121	44.10	1120.21
L_MARIO2_R_05884	0	34	83	0	117	0.121	44.21	1122.84	0.120	43.88	1114.64
ALL2R_HA469	365	49	0	6	420	0.100	36.56	928.58	0.120	43.68	1109.47
BEELINE_R_05963	6	13	55	0	74	0.129	47.18	1198.43	0.129	47.19	1198.53
MC_COY_16634	0	1	0	17	18	0.124	45.42	1153.61	0.123	44.87	1139.82
PINE_ISL_R_05876	33	37	0	33	103	0.112	40.75	1035.14	0.119	43.35	1101.15
KISS.FS2	14	0	0	13	27	0.125	45.49	1155.43	0.127	46.21	1173.834

2.3 Reference Evapotranspiration

Evapotranspiration data or weather data were available at three stations. Weather data covering 1990-2000 (total radiation, temperature and humidity) were available at station S-61 located on canal C-35 just downstream of Lake Toho. At station WRWX, located on the southern boundary of the model area (see Figure 2-2) weather data were available for April 1997 through January 2001. Finally pan-evaporation data were available for station KISS.FS_E_6378 for the period 1980 through April 1999.

Only minor data gaps were found in the weather data files while the pan evaporation contained numerous smaller and larger data gaps. For S-61 data were missing for November and December 2000. Solar radiation data from S-61 measured in November-December 1999 were used as replacement.

It was initially chosen to use weather data only from station S-61 to calculate reference ET. Station WRWX could have been used for the southern part of the catchment but S-61 data are probably equally representative. The pan evaporation data contained numerous data gaps and it was considered more feasible to base reference ET calculations on only one methodology rather than combining reference ET calculations from weather data with pan evaporation data. However, data flaws were identified for the period April 1996 through August 1999. The radiation data showed a clear shift with substantially lower values for the mentioned period. When compared to solar radiation data measured at WRWX the S-61 values were considerably lower. Thus, it was agreed that the radiation data measured at S-61 were not reliable for the above mentioned period. Station WRWX contained data from starting from July 1997. These data were compared with other radiation data from South Florida and seemed to be realistic. The WRWX data file contained both total radiation and net radiation data. The net radiation data were used to calculate reference ET using the Priestley-Taylor method. The Priestley-Taylor have previously proven suitable for South Florida's humid climate where solar radiation is the single most important parameter for the reference ET (Abtew and Obeysekera, 1995)

The calculation procedure is described in the following section.

2.3.1 Calculation of Reference ET using Priestley-Taylor

The Priestley-Taylor model reads (Abtew and Obeysekera, 1995):

$$ET = \frac{1}{\lambda}\alpha\left[\frac{\Delta}{\Delta+\gamma}\right](R_N - G)$$

Where ET is reference ET (mm d^{-1}), Δ is slope of vapor pressure curve (kPa $°C^{-1}$), γ is the psychrometric constant (kPa $°C^{-1}$), R_n is net radiation (MJ m^{-2} d^{-1}), and G is water heat flux (MJ m^{-2} d^{-1}), with a modified α value of 1.18. The various terms in the Priestley-Taylor equation were calculated based on Smith, M. (1990) as described below.

The slope of vapour pressure curve was calculated using equation (3) in Smith, M. (1990):

$$\Delta = \frac{4098 e_a}{(T+237.3)^2}$$

T : Air Temperature [°C]

e_a : Saturation Vapour Pressure at Temperature T [kPa]

e_a was calculated using equation (10) in Smith, M. (1990):

$$e_a = 0.611 \exp\left(\frac{17.27T}{(T+237.3)}\right)$$

The psychrometric constant (γ) was calculated using Smith, M. (1990) equation 4.

$$\gamma = 0.00163\left[\frac{P}{\lambda}\right]$$

where P is the Atmospheric pressure (kPa) and λ is latent heat (MJ kg^{-1}). λ varies only slightly over normal temperature ranges and was kept constant at 2.45 MJ kg^{-1} (Smith, M.,1990, equation 2).

The water head flux (G) was calculated based on daily temperature fluctuations as:

$$G = 0.38(T_{day,n} - T_{day,n-1})$$

Where $T_{day,n}$ is Temperature (°C) in day n and $T_{day,n-1}$ is Temperature in previous day (Smith, M.,1990, equation 65).

The calculations were done using an EXCEL spreadsheet which is also included on the project CD-ROM. Figure 2-3 shows the measured solar radiation and the cumulated calculated reference ET. Solar radiation was used from July 1997 through December 2000. Daily reference ET for 1995-1996 was calculated as the average value (daily) for the period January 1998 through December 2000.

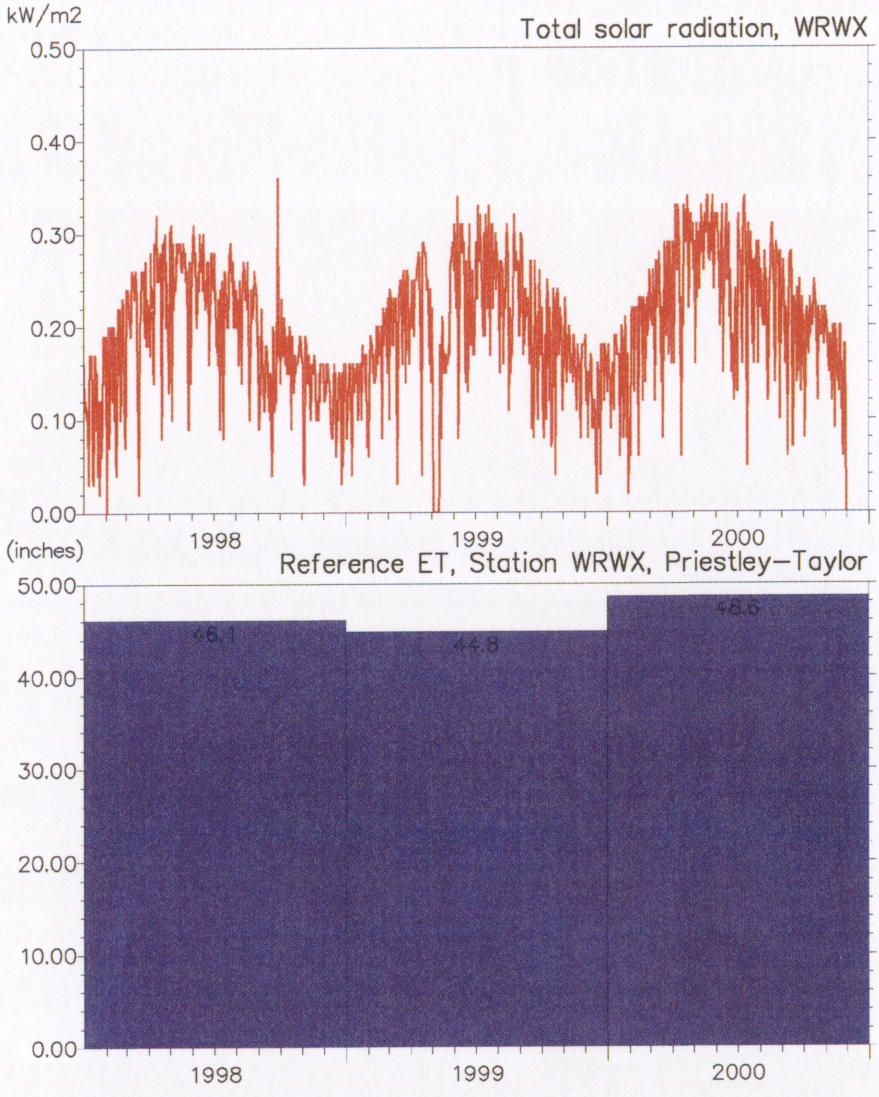

Figure 2-3 Cumulated Yearly Reference ET and measured daily solar radiation at station WRWX

2.4 Data and Programs Used for ET and Rainfall Processing

Table 2-3 List of Data Files and Utility Programs Used to Develop Rainfall Data

Description	Data File on Project CD-ROM	Comments/file type
Rainfall Time series data in T0 format for individual gauges	TIME/Rainfall-gapfilled-newdata.T0	MIKE SHE T0 time-series data converted from DBHydro.
Rainfall data for stations used in model	Gapfilling/rain_inches-new-data.dfs0	DHI dfs0 time-series data file containing rainfall data with gaps. First value after a data gap was removed manually.
Rainfall data for stations used in model	Gapfilling/rain_inches-filled-new-data.dfs0	As above but gap-filled.
Spreadsheet for making gap filling statistics	Gap filling/statistics.xls	EXCEL spreadsheet file.
Spreadsheet for calculating reference ET from WRWX net radiation	Data/meteorology/WRWX-ET0.XLS	EXCEL spreadsheet file.

3 REFERENCES

Abtew, W. and J. Obeysekera (1995). Lysimeter Study of Evapotranspiration of Cattails and Comparison of Three Estimation Methods. Transaction of the ASAE 38(1):212-129.

Smith, M. (1990). Expert Consultation on Revision of FAO Methodologies for Crop Water Requirements. Rome, Italy, 28-31 May 1991.